Space Weather Technical Forecast

Issued on Saturday, 16 September 2023 at 01:13 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G2 Likely late UTC day of Saturday into Sunday. Chance of further G1 Monday. Chance R1 throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the past 24 hours, with an M1.7 flare, peaking at 15/2229 UTC, originating from AR3429, near centre-disc. This region has been the source of recent M-class flare over recent days. There are currently seven sunspot regions on the visible disc. The most complex group on the disc is now perhaps AR3429 near centre-disc, with a Mt Wilson delta spot remaining in its central portion, however its growth has now stalled. Other sunspots on the disc were generally both simpler and in decay, including all of the remaining three larger bipolar groups, AR3425, AR3430 and AR3423.

There is a large filament lying to the north of AR3429, which is prone to instability should a significant flare occur from the active region, especially near its southern portion in its 30 degree plus span. Also of note with this feature is the fact that it is a very poor fit to the (HMIBC) magnetic neutral lines underlying it at present (Udaipur H-Alpha 15/0650UTC and HMIBC for same time) - it appears to lie wholly within a mainly negative magnetic polarity region, rather than on any boundary. The reason for this is uncertain, but is perhaps due to its altitude (chromosphere) relative to the source for the HMIBC signal (photosphere); else perhaps there are sharp gradients in the field orientation here; or perhaps the support for this feature is breaking down. Whatever the mechanism for its unusual presentation, this is a feature which will continue to be monitored.

A visually weak CME seen heading south and east late on Thursday evening coronagraph imagery has an uncertain attribution, however may be linked to the largest flare from AR3429 in the previous 24 hour period. This has been modelled and shows a tentative side lobe hit in the UTC morning of day 3 (Monday 18 September). The strongest evidence found for this CME is AIA304 imagery in the hours following the flare, with an apparent helicoidal dark emission seen heading slightly southward from the vicinity of AR3429. There was a near-simultaneous large disappearing filament observed from the northwest quadrant in the same imagery. This may be tied to an apparently northward-directed slow CME in the early hours of Friday 15 Sept, although appears to be off-ecliptic and not considered to be Earth-directed.

No other Earth-directed were observed in the past 24 hours.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by DSCOVR (as well as ACE and STEREO A) near L1, were perhaps most indicative of a possible CIR that did not fully evolve into its associated fast wind - this may be the result of skirting the southern limits of CH44/+, although the phi angle has remained negative (towards the Sun) throughout. ACE EPAM LEMS showed elevated low energy proton levels over this timeframe, and failed to show a sharp drop usually observed on commencement of any fast wind. The solar wind speed has been slightly elevated throughout, between 430-490km/s. Density has been mostly around the average, although started the period slightly above average. The interplanetary magnetic field

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(IMF) was mostly weak or moderate, peaking at 8nT, with the all important north-south component (Bz) varying between +7 and -5nT. Geomagnetic activity has a result of the above solar wind parameters was Quiet (Kp 1-2) throughout the period.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was a background levels. GOES16 high energy (greater than 2MeV) electron flux was at Normal Background to Moderate levels. The associated 24-hour fluence was well below the Active threshold, with 3.91e6 integrated pfu observed at 16/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a daily Chance of M-class flares, mainly from AR3429 near centre-disc. The large but fading AR3423 should leave the Earth-facing side over the coming UTC weekend, but the flare risk may be maintained by the return of Ex-AR3413 in the east, which may be the source for some large recent far-sided CMEs and, by inference, large flares.

Solar Wind / Geomagnetic Activity: The geomagnetic forecast is of lower than average confidence, for a full discussion please see the Geomagnetic Storms section.

The main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME. An initial Slight Chance of G1 from the 11 September CME and CH47/- will give way to a Chance of G2 later in the UTC day of Saturday 16 September, and going into Sunday 17. From here, a further Chance of G1/Minor Storm from the 14/2126UTC CME follows on Day 3 (Monday 18 September), with effects waning by Day 4 (Tuesday 19 Sept).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a Slight Chance of an enhancement should any larger flares occur.

High energy (greater than 2 MeV) electron flux is likely to be suppressed at Normal Background levels at GEO through much of the period, but perhaps with an eventual increase in the wake of CH47/-, now rendered lower confidence by intervening CMEs. Overall, the 24-hour fluence is Expected to remain below the Active threshold throughout the period, with reducing confidence into the new UTC week.

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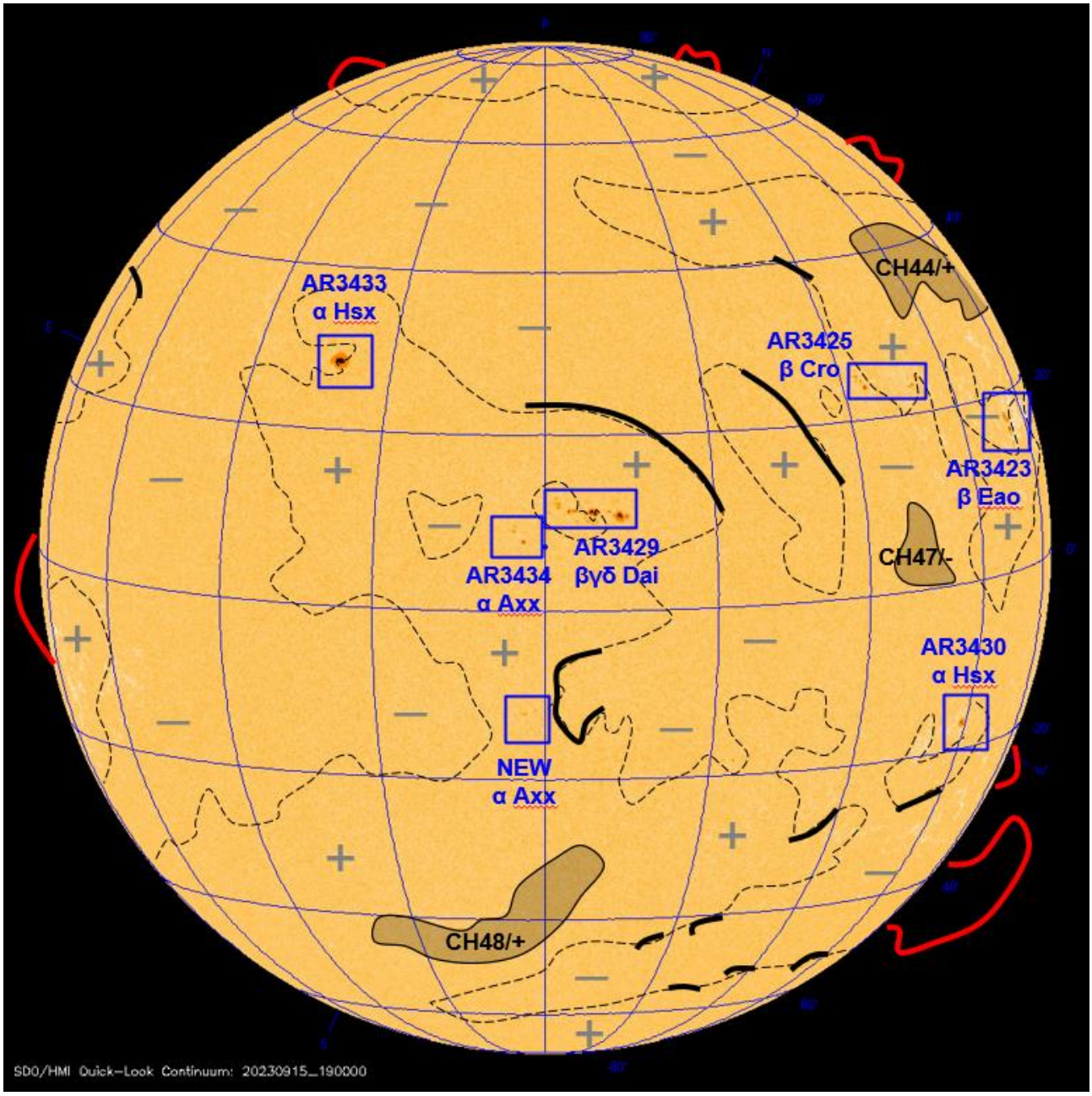
Figure 1. Solar Analysis Valid 15/1900UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
The geomagnetic forecast has become more complex in the last 24 hours. The fast wind from CH44/+ has not materialised as forecast, with the most likely course of events now being that Earth has seen glancing influence from its CIR during the previous 24 hour period, which has no waned. Its succeeding coronal hole, CH47/-, is perhaps more likely to connect for lying near the solar equator, although being of negative polarity and only having attained Kp3 on last pass, it is not likely to be significantly impactful.

There are currently three CMEs that feature in the forecast:

The first CME resulted from a filament eruption in the south-centre disc around 11/1400UTC. This gave a CME which appeared slow, largely southward-directed and relatively faint in imagery. Analysis has shown that this may give Earth a weak glancing blow in the next 24 hours. Overall, little effect on geomagnetic activity is expected from this CME - if it arrives at Earth.

The second CME was from a large filament eruption in the northwest, associated with an M1.4 flare near AR3423 around 14/0745UTC. This feature was mainly directed north and west of the Sun-Earth line, however a partial halo shock (at least) was observed, and there is a reasonable chance of the edge of the main CME may impinge on Earth. Confidence in the analysis itself is low due to the single perspective available at present (L1), however it has been rendered lower still by MOSWOC Enlil's relatively poor grasp of antecedent conditions - the model had signalled a 500km/s+ fast wind for two days prior to the eruption, and brought them down as CH44/+ and CH47/- were expected to affect Earth in turn. It is partly for this reason that the arrival time of the M1.4 CME has been adjusted to 16/1800UTC rather than the modelled 16/2200UTC, which is on the advanced end of ensemble solutions. This is perhaps now on the more pessimistic side of arrival time estimates, given the very short duration of CH44's CIR to 500km/s, when a more sustained speed was envisaged.

The third and final CME was likely associated with an M2.4 flare from AR3229 at 14/2126UTC, although imagery for this event is scant. Although the flare was narrowly in the northeastern quadrant, the CME appears to be directed slightly south and east, with consensus opinion suggesting possible arrival around 18/0900UTC, although this is somewhat dependent on its precursor(s) and how they modify the interplanetary environment.

All considered, the geomagnetic forecast is of lower than average confidence. The main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME. An initial Slight Chance of G1 from the 11 September CME and CH47/- will give way to a Chance of G2 later in the UTC day of Saturday 16 September, bleeding into Sunday. From here, a further Chance of G1 from the 14/2126UTC CME follows on Monday 18 September. Becoming mostly Quiet to Unsettled by day 4 (19 Sep).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	No	60	40	50	10
Strong	**G3**	No	10	10	1	1
Severe	**G4**	No	1	1	1	1

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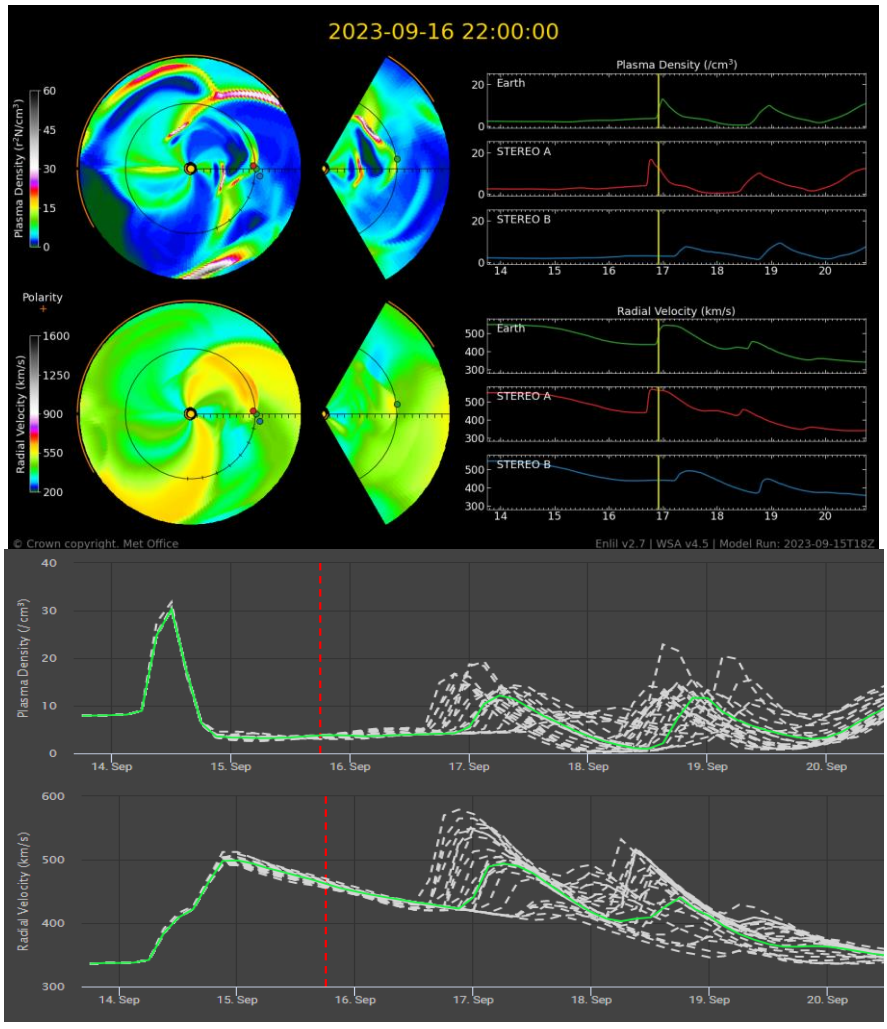
Extreme	**G5**	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
14/1159	Partial	Filament eruption	NW near AR3423	830km/s	16/1800 UTC	Arrival adjusted forwards due to model background deficiencies. Reasonable chance of hit.
15/0600	Partial	AR3429	M2.4 flare	500km/s	18/0900 UTC	Edge hit. Low confidence.

Figure 2: MOSWOC Enlil and ensemble shows potential CME arriving later in the UTC of Saturday 16 September with effects possibly lasting into Sunday 17 September. Another CME could give a glancing blow at Earth on Monday 18 September.



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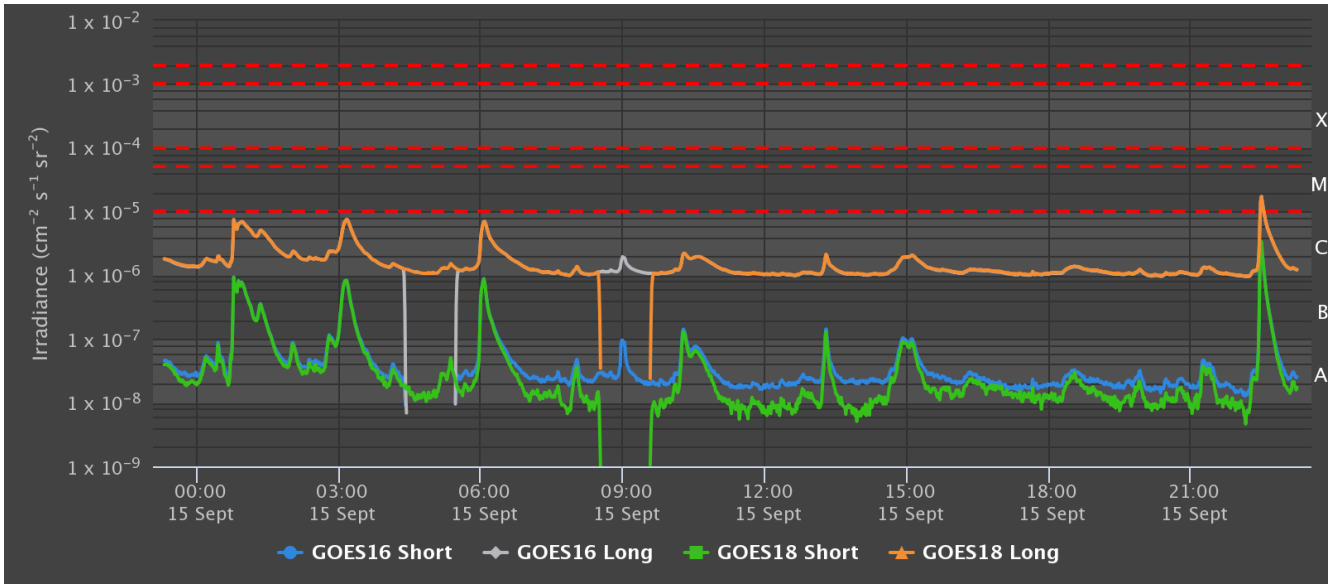
Radio Blackouts - X-Ray Flares:
The focus of attention is now shifting from the decaying and relatively far westward AR3423, to the more centrally-located AR3429. So, while the gradual areal decay of all the bipolar groups except AR3429 in the last 24 hours has meant that the whole disc probability has fallen. However, these values may be revised again if any significant flaring occurs from AR3429, especially give the presence of a Mt Wilson delta spot (with the raw disc figure derived from Zurich class).

In terms of the forecast, AR3423 is expected to rotate off the visible disc over the UTC weekend, however, far-side sounding data suggests that a large region is expected to rotate over the eastern horizon to mitigate against any otherwise declining risk. This arriving region is expected to be the returning Ex-AR3413, which was responsible for numerous M-class flares during when last on the visible disc. A number of large, far-sided CMEs can likely be attributed to the region in the past several days, suggesting it is still active and has survived its transit on the far side.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES X-Ray flares



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is expected to persist at Background levels. There remains a daily Slight Chance of flux levels rising in response to any significant flaring, with the focus now moving from AR3423 (currently near the western limb) to central AR3429 towards the end of the forecast period.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

High Energy Electrons Event (≥ 2MeV):

High energy (greater than 2MeV) electron flux levels are now lower confidence than in recent guidance due to the presence of potentially Earth-directed CMEs, as well as the lack of any fully-fledged high speed stream from CH44/+. CH44/+ may now have missed Earth narrowly to the north of the ecliptic plane, with Earth perhaps instead skirting its associated southern-delimiting CIR.

Being nearer the solar equatorial plane, CH47/- is a more assured feature for connection, perhaps coming within the current UTC day. Even if Strong solar winds are seen as on last pass with this feature, the fact that these did not result in Active fluence perhaps increases confidence in their remaining below threshold, even with the complicating CME influence the UTC weekend.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	5	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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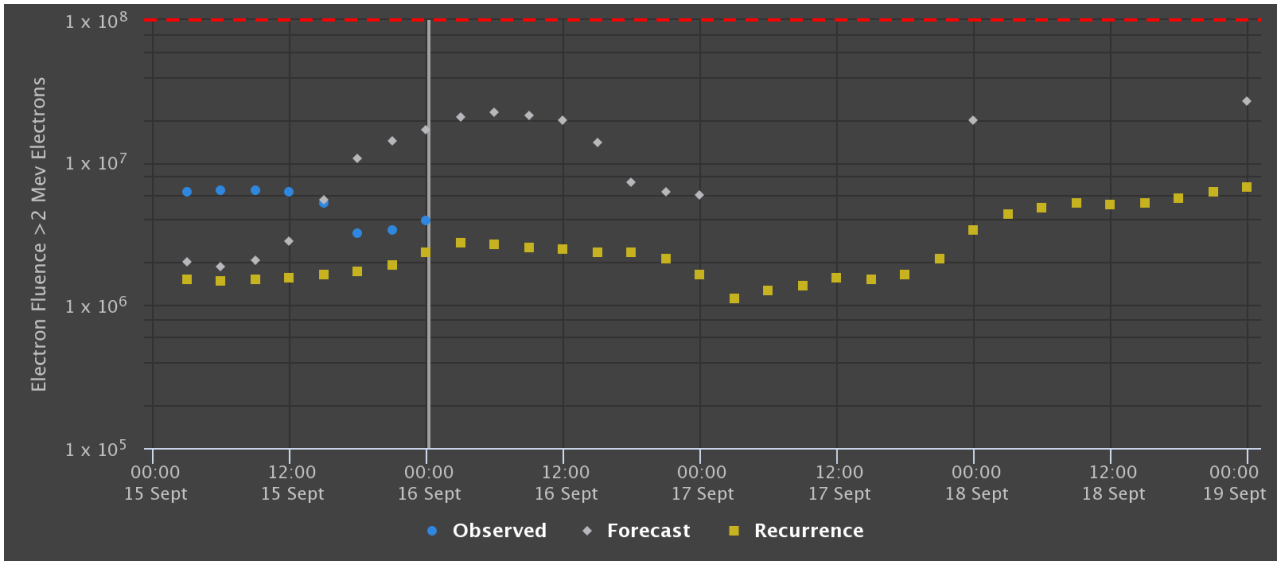
Figure 4: MOSWOC REFM electron fluence, observations and recurrence



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